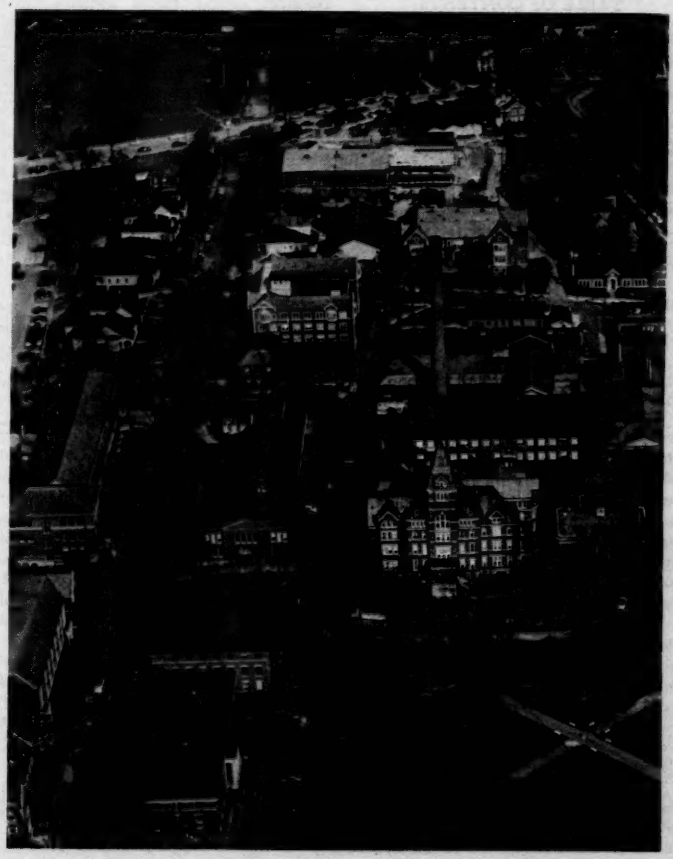
STATE ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA INSTITUTE OF TECHNOLOGY

MAY ATLANTA, GEORGIA 1951



The Research Engineer

Published in May, September, November, January, and March by the State Engineering Experiment Station of the Georgia Institute of Technology, Atlanta, Georgia. 1951-1952 Volume, Number 1. Entered as second-class matter September 20, 1948, at the post office at Atlanta, Georgia, under the Act of August 24, 1912. Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, Section 538, P.L.&R., authorized October 18, 1948.

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INDIVIDUAL FACULTY RESEARCH

Anyone asked to define the necessary functions of a top-flight engineering school would undoubtedly state that it should educate young men for the engineering professions and that it should pursue a rigorous program of research. Some might expand their definitions to stipulate that the educational function should include a graduate school in which students can prepare themselves for creative research and demonstrate their abilities to carry out such research independently. The definition formulators would probably also specify that the institution should maintain an engineering experiment station staffed with full-time professional research personnel to prosecute major research projects for the benefit of industry.

These definitions are fine—as far as they go—but they do not cover one function which can lift an engineering

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The trend toward management of business and industry by engineers has emphasized the role of engineering colleges in training the leaders of tomorrow. Once it was a common belief that engineers, while indispensable in design, construction and production, were too specialized to head vast enterprises. Today, there is increasing realization that scientific training is an extremely important asset in company executives. Chemical, civil, aeronautical, mechanical and other engineers now head a number of large companies and direct the vital operations of many more. As industry has turned to modern technology for new and better processes and products, it has also turned to engineers to plot its more complex course.

This places an added responsibility upon engineering education. The engineer of today must be equipped with more than the basic engineering knowledge considered sufficient for his accepted functions of yesteryear. If he is to grow with experience to a position of leadership, he must be provided while in school with an understanding of the principles of economics and management. Besides an insight into the intricacies of business ethics, labor relations and related subjects, the engineer should be soundly grounded in the spoken and written use of his native language so that he can lucidly report his work and effectively defend his ideas.

Our engineering schools are aware of their responsibilities. Our curricula have been broadened to provide the required training, and we are confident that a substantial number of our students will prove equal to modern industry's need for scientifically trained executives.

BLAKE R. VAN LEER,

President, Georgia Institute of Technology

NEW ROLES FOR THE UNIVERSITIES IN THE DEFENSE PROGRAM

By ERIC A. WALKER*

On April 27, Dr. Eric Walker presented the following address at a luncheon following the annual joint meeting of the Board of Trustees and the Advisory Council of Georgia Tech Research Institute and just prior to dedication of Tech's Hinman Research Building. Because of its timely message to the universities of our country, this address is printed here.

Dr. Eric A. Walker

In accepting the invitation to be with you on this pleasant occasion today I feel that I am, in a limited sense, returning the visit of your distinguished President, Dr. Van Leer, who served a little less than a year as Chairman of a special committee of the Research and Development Board. Upon Dr. Van Leer and his able associates we placed the rather onerous task of selecting a site for the eleven million dollar Army Quartermaster Research Laboratory, the location of which had been a hotly debated subject for some time. I do not feel that my presence here today nor the slight amount of information I might impart in these remarks in any way repays the very real debt which we owe Dr. Van Leer for a task well done. Nevertheless, it is most agreeable to share with you your pleasure and satisfaction in this fine addition to your plant. The dedication of this building is somewhat symbolic of the dedication of the universities throughout the country to a relatively new form of public service. Since World War II, colleges and universities have come to play an increasingly important role in the defense effort. A distinguishing feature of that activity has been the research contract. The Office of Scientific Research and Development, with whose activities everyone is now familiar, had contracts with approximately 150 academic and other nonprofit institutions. Practically the entire United States radar program stemmed out of the Radiation Laboratory at the Massachusetts Institute of Technology. The University of Chicago played an important part in the atomic energy program, and the California Institute of Technology was the center of U. S. rocket research. These are but three of many illustrations I could cite. After the OSRD went out of business, the military services continued to sponsor many of its contracts and, in addition, have written new ones of their own. The military research and development program is having a profound effect upon the national research and development effort in general, and its impact upon the universities is such as to bring up new problems and considerations.

To state the situation in its baldest terms at the outset: the military program and the atomic energy research and development program together account for nearly two-thirds of the national expenditure for research and development. The Atomic Energy Commission and the Department of Defense either directly or through contract engage the services of about two-thirds of the nation's research scientists and engineers. The expanding programs of both agencies are expected to absorb something like three-fourths of the national supply of scientific manpower engaged in research. The growth of the military research and development program is most graphically illustrated by comparison with the figures of only a decade ago. Prior to World War II, the total annual expenditure for research and development by the War and Navy Departments was less than thirty million dollars a year and remained near this level even during 1940 when it was obvious that war was imminent. Thanks to the foresight of a small group of eminent scientists who carried their prophetic message to the President, the United States was early aware of the potentiality of new scientific developments

**Executive Secretary, Research and Development Board, Dept. of Defense.*

in the coming struggle. During World War II the military research and development effort climbed to 500 million dollars of which approximately two-thirds was spent by the War and Navy Departments and the remainder by the Office of Scientific Research and Development. The growth of the military effort coincided with a similarly remarkable growth in the national effort. During the war, the research capacity of the country measured in dollars climbed from 300 million dollars to one and three-quarters billion dollars.

At the same time the status of the scientist and research worker underwent a marked change. The "long hairs" who had been the butt of so many good-natured jokes now found their services widely sought after. Government, industry, and education competed with each other for scientists, engineers, and technically trained workers of all types. All three did their best to snatch these prized employees away from the demands of the Armed Services. Since there were not enough to go around, many of the top men worked on government contracts, fulfilled teaching obligations and served as consultants at the same time. Undoubtedly, many of you here today were or are carrying such triple burdens. We learned, also, that the most efficient use could be made of specialized skills by according senior scientists sufficient clerical and technical help to free them for the essential tasks of which they alone were capable.

It now looks as though the military research and development effort, which maintained a fairly constant level at a half-billion dollars in the post-war period, will go well over the billion dollar mark in the current fiscal year. Although there are continuing demands for new and better weapons and for the exploration of many possibilities, it is obvious that the program must level off somewhere because of the limitations imposed by the shortages of trained personnel. As I see it, the universities are faced with the nice problem of maintaining teaching staffs adequate to turn out trained scientists and engineers in spite of curtailments which might be necessary in face of reduced enrollments growing out of the selective service requirements. At the same time they are being called upon to fulfill defense contract commitments and to lend the services of available staff members as part-time consultants, and specialists. It may be that contractual work will provide the means whereby the universities may hold their staffs together even though enrollments are down. It is, of course, an advantage to the Government to be able to avail itself of the special skills afforded by research teams who have learned to work well together.

Important as the contractual program is, however, I do not believe that it represents the most important contribution which the universities can make to the national welfare and to the defense program. To my mind, the most important contributions which the universities can make is to constitute themselves strongholds of basic research, which is so fundamental to our continuing technological advancement, and to produce in the greatest numbers practicable the trained scientists and engineers which are the limiting factors in our present program of research and development.

Although the Georgia Institute of Technology is primarily dedicated to the practical arts, I should like to make a passing observation with respect to the importance of basic research. The university is traditionally the home of explorations into the realm of pure knowledge. With the increasing demands of production, military research and development, and other requirements of our highly technological society, there is some danger that basic science, with no objective but to add to the sum and total of man's knowledge may be crowded out of the picture.

With this thought in mind, the Research and Development Board early this year announced a new formula by which departmental support of basic research will be a fixed percentage of each military department's average annual total research and development budget for the last five fiscal years. Under this formula the total Department of Defense expenditure for basic research must be at least 30 million dollars in the current fiscal year. The only qualification which ties this policy specifically to the Department of Defense is that the studies supported by these funds must be in the

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DISTILLATION OF WOOD AND COAL BY THE FLUIDIZED POWDER PROCESS

By H. C. LEWIS*

Some years ago distillation of wood and coal was the only commercial source of a number of basic chemicals. Today, the manufacturers of coke and the distillers of hardwood and pine stumps have lost ground to a variety of competing processes. The following article describes work in progress at Georgia Tech and elsewhere, which may lead to improvements in the distilling operation.

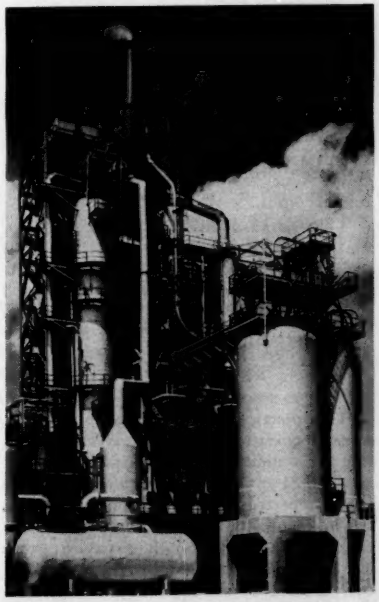
For three quarters of a century the products obtained from distillation of wood and coal have been an important source of raw materials for the chemical industry. When either of these materials is heated in the absence of air, gases are evolved which contain a variety of useful chemical compounds. Thus, the gases given off during the production of metallurgical coke are a major source of ammonia, benzene, toluene and a number of other compounds in smaller amount, while the distillation of hardwood is a time-honored method of securing wood alcohol, acetic acid and other chemicals. The distillation of pine stumps to produce turpentine, pine oil and rosin is an operation familiar to the southeastern part of the United States.

In recent years, all of the processes for the distillation of wood and coal have been meeting competition. The coke industry has had to face the production of toluene and other chemicals from petroleum, as well as the efforts of petroleum companies to develop processes which will permit the substitution of gas for coke in the manufacture of steel. The wood alcohol industry has been hard pressed by synthetic methanol and acetic acid, and the distiller of pine stumps has had to compete with the newer processes for recovery of turpentine and pine oil by solvent extraction.

Shortcoming of Present Process

The fact that all of the industries based on the distillation of wood or coal in the absence of air have been running into increasing competition suggests that there may be some major shortcoming in the operation as it is carried out at present. That this is indeed true is revealed by a consideration of the details.

A most important point to keep in mind is that the nature and amount of the chemical compounds evolved during the heating of wood or coal in the absence of air are determined by the heating cycle to which the material is subjected. Hence, if a maximum yield of the most valuable products is to be secured, each and every particle of



Fluid catalytic cracking unit of the Ohio Oil Co. at Robinson, Illinois.

*Associate Professor of Chemical Engineering.

the charge must be subjected to the same schedule of time and temperature, as nearly as possible, and the schedule must be the proper one for production of maximum yields. This demands a close control of the temperature throughout the charge at all times during the distillation.

Unfortunately, the nature of wood and coal is such that close control of the temperature is extremely difficult in all the types of apparatus customarily used. In the heating of wood, for example, one finds that heat transfer is very slow because of the existence of pores, which are initially filled with air and later with gases evolved from the wood itself. Because of the low thermal conductivity of gases, the pores act as natural insulators. As the distillation of wood or coal proceeds, more pores are formed as a result of the removal of water, tars, etc., from the original material, and the insulating effect is multiplied. In a bed of chunks or particles there is a further insulating effect due to the gases between the particles. Perhaps as good an illustration as any of the difficulty of transferring heat through a bed of particles of wood is the fact that sawdust has been used successfully for many years as an insulating material in ice houses. It is said that a century ago an enterprising Yankee trader was able to ship ice, packed in sawdust in the hold of a sailing vessel, all the way from New England to India.

There is an additional complication. In the distillation of hardwood there is a range of temperature in which large quantities of heat are given off by the wood itself as a result of some of the chemical reactions which take place. The distillation of coal is characterized by a range of temperature in which there is a tendency for the coal to be plastic.

The practical result of the poor heat-transfer characteristics of wood and coal is that it is difficult to get heat into or out of a bed of any thickness without setting up high temperature gradients. The tendency is to "overdo" the portions near the source of heat and "underdo" those farthest from it. In consequence, the unsatisfactory alternatives faced by the engineer have been that he has either had to accept relatively low yields of valuable chemicals for the sake of high heat-transfer rates and high capacity of the apparatus, as in by-product coke ovens, or accept low heat-transfer rates and low capacity for the sake of better temperature control and yields of chemicals, as in the distillation of hardwood.

Distillation by the Fluid Process

In contrast to the poor heat transfer which is so characteristic a handicap of the various ovens, retorts and kilns now in use in the distillation of wood and coal are the excellent heat transfer and temperature control achieved in the fluidized powder process developed by the petroleum industry during the last decade. The new process is essentially a technique for contacting a solid with a gas by suspending the powered solid in an upward moving stream of the gas under such conditions that the solid forms a dense, but highly agitated bed. Under these conditions heat transfer is so rapid that temperature inequalities within the bed are almost completely ironed out. The turbulence ensures rapid transfer of heat from the gas to the surface of the particles, while their small size makes it easy for heat to flow from the surface to the interior. Even more important, powdered solids have a tremendously greater surface area than do substances less finely divided, and the reactions involved in distillation consequently occur much more rapidly.

In large commercial reactors, fifty feet high, the temperature difference between the top and the bottom is found to be no more than five or ten Fahrenheit degrees at the most. Because of this characteristic, the process has been found by the petroleum industry to be particularly suitable for operations requiring exact control of the temperature, and has been used on a very large scale in the manufacture of gasoline.[1] The technique is also being used successfully in the manufacture of phthalic anhydride and the calcination of lime, and development work is in progress on a number of other applications.

The favorable characteristics outlined above suggest application of the fluidized powder technique to the distillation of wood and coal. In the coke industry, for example,

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THE CORRELATION FUNCTION

By I. E. PERLIN*

Mathematics has been termed "Queen of the Sciences" in recognition of the dependence of all other sciences upon it to express the exact relations existing between quantities and, in accordance with these relations, to calculate unknown, difficultly measurable quantities from other quantities known or directly measurable. The autocorrelation function described here is becoming a tool of great importance to the research engineer—successful applications including study of Brownian motion, colloidal statistics, thermodynamics and the theory of cosmic rays. Detection of radar signals in the presence of noise, design of fire control systems, analysis of business trends and weather forecasting are some other fields in which application of this function is under study. The following article explains some of its mathematical properties and its application to the harmonic analysis of random processes.

The application of statistical theory to engineering research is developing at a rapid rate. The purpose of this article is to describe some of the important ideas of mathematical statistics, and to point out how they can be employed in research. The correlation function occupies a central position in the problem of analyzing a random process harmonically.

If repeated experiments are performed under essentially the same conditions, results are obtained which are similar but not identical. For example, the result of an experiment may be expression of the voltage as a function of time. Many experiments performed under essentially the same conditions will yield not a single function, but an ensemble of functions. Such an ensemble of functions is called a random process. The mathematical analysis of a random process is concerned with the determination of its statistical characteristics.

Another convenient way of thinking about a random process is to visualize it as a single function whose values are not specified by some analytic expression but rather through probability expressions. To illustrate this, consider a coin tossing experiment. If heads turns up, set $x(t)=a$ in $(o<t<h)$. If tails turns up, set $x(t)=-a$ in the same interval. Tossing again would yield either a or $-a$ for the interval $(h<t<2h)$, etc. The random process resulting from repeated experiments could then be visualized as a wave of rectangular pulses of constant duration h appearing consecutively each with equal probability of being positive or negative. Such a wave is illustrated in Figure 2, and shall be analyzed later.

In the development of the analysis of a random process, the process shall be thought of as an ensemble of functions depending on time. A random process is shown in Figure 1. At an arbitrary time t_1 observations are made on the ensemble yielding a set of values x_1', x_1'', x_1''', one from each of the functions in the process. A distribution function $\omega(x_1)$ is determined so that $\omega(x_1)dx$, is the probability that the values observed lie between x_1 and $x_1 + dx_1$. Next, observations are made at two different times t_1 and $t_1 + \tau$. A second distribution function $\omega(x_1, x_2; \tau)$

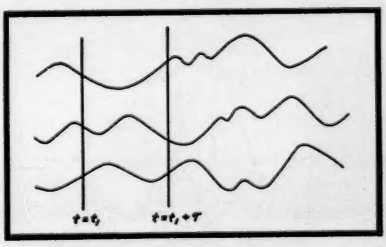

Figure 1.

*Associate Professor of Mathematics and Research Associate of the Engineering Experiment Station.

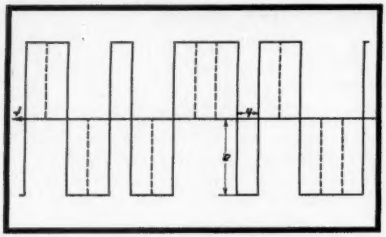

Figure 2.

is determined so that $\omega(x_1, x_2; \tau)\, dx, dx_2$ is the joint probability that the observed values at t_1 lie between x_1 and $x_1 + dx_1$ and the values at $t_1 + \tau$ lie between x_2 and $x_2 + dx_2$. The third and higher order distribution functions are obtained in a similar manner. The infinite set of probability distribution functions determines the random process.

It is assumed that the distribution functions are invariant under translation in time. Such a random process is called a stationary process. In practice only the first and second distributions are required. While the first distribution is generally simple to obtain, the determination of the second distribution is quite complicated. Because of the difficulty in obtaining the second distribution function,

$$(1)\qquad \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2 \omega(x_1, x_2; \tau)\, dx_1\, dx_2,$$

another function, which is the mean product of x_1 and x_2 as a function of their separation time τ, is employed. The function given in Equation (1) is comparatively easy to evaluate analytically.

If $x(t)\ (-\infty < t < \infty)$, is one of the functions of the random process, then

$$(2)\qquad \phi(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x(t)x(t+\tau)\,dt$$

is called the autocorrelation function of $x(t)$. Another important hypothesis in the theory of stationary random processes known as the ergodic hypothesis states that the function given in Equation (1) is equivalent to the autocorrelation function given in Equation (2) for a member function of the process. Thus the autocorrelation function is seen to be an important statistical characteristic of a random process.

Before stating the properties of the autocorrelation function of a stationary random process, some examples shall be considered. In Figure 2 is shown a series of rectangular pulses of the same duration h appearing consecutively, each with equal probability of being positive or negative.

The autocorrelation function is

$$\phi(\tau) = a^2\left(1 - \frac{|\tau|}{h}\right) \qquad |\tau| < h,$$

$$\phi(\tau) = 0 \qquad |\tau| > h,$$

and is shown in Figure 3.

Next, consider a flat top wave of alternating positive and negative pulses of varying duration as shown in Figure 4.

The assumption made in this problem is that the distribution of the zero crossings obeys the Poisson Law which states that if K is the average number of zero crossings per second, then the probability that there

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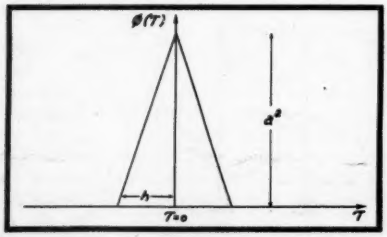


Figure 3.

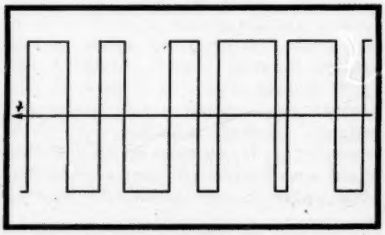


Figure 4.

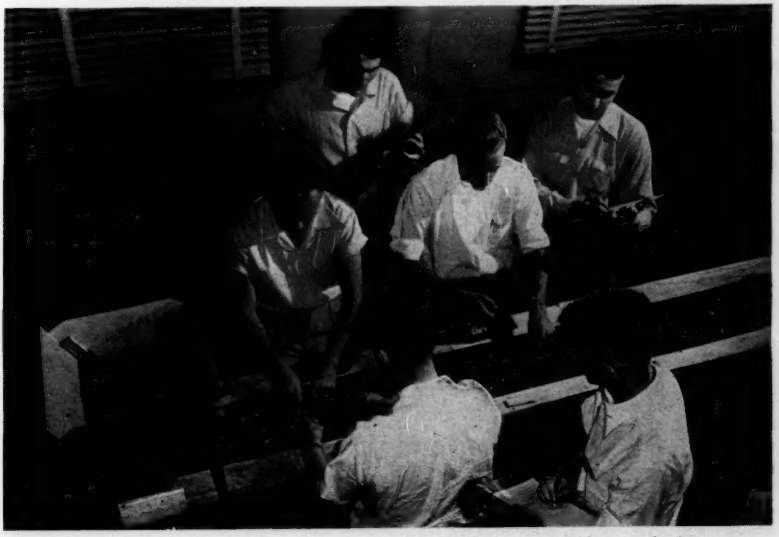
INDUSTRIAL ENGINEERING AND SOUND MANAGEMENT PRACTICES

By JOHN M. AVENT*

Horsepower, revolutions per minute and shut-down time are typical factors which determine a machine's output and, as such, are the concern of every engineer. Similarly, man's productivity is determined by somewhat analogous factors, the study and control of which are the province of the industrial engineer. Fortunately, human beings are endowed with certain inherent capabilities and limitations subject to standardized measurement, and the majority respond predictably to conditions of work and recompense. Thus, the industrial engineer can often predict human output and recommend optimum conditions for maximum production. In the following article, Prof. Avent briefly describes the present status of industrial engineering and the philosophy of sound management. In later issues, he will write in detail on the various phases involved, including job analysis, wage incentive, synthetic time standards and related factors.

The management of industrial operations is emerging from the realm of crystal ball gazing and rule-of-thumb practices at an accelerating pace. Industrial Engineering and Management as a profession is gaining wide recognition as a necessary part of our expanding competitive economy. Real wages and real profits can only be increased by producing more goods at less cost. Both labor and management have discovered that the mere possession of dollars is no guarantee of a high standard of living. The question is "How much will your dollars buy?" If more goods can be turned out at less cost,

*Professor of Industrial Engineering, Georgia Institute of Technology, and Consulting Industrial Engineer.



Time measurements being taken in a study of peanut picking methods.

Motion time measurements are facilitated by the use of a wire recorder.

then both labor and management will have more useful dollars. In other words, the purchasing power of the dollar will be increased. The job of professional industrial engineers and management people is to see that the standard of living of the employees and business owners is ever increasing. There is no business too small or too "different" to profitably apply some of the professional industrial engineering and management techniques that are now being used on an ever increasing scale.

Not so long ago it was common practice to operate a plant without knowing what each product cost. These days enlightened management not only knows the cost of each product after it is produced, but it can determine with accuracy the cost of manufacturing a product *before it is produced*. Predetermined elemental time standards make it possible to man a new plant and determine costs of new products accurately in advance of production. Although the physical equipment of each plant is different, the physical equipment of the human beings who operate the machinery is the same. Each human is equipped with hands, legs, eyes and a body. With this standard equipment the human can do only certain things. He can reach, grasp, position, turn, bend and so forth. These elemental motions have been classified and standard times have been set for them, so that except where process time is involved it is no longer necessary to use a stop watch in order to set time values for cost purposes. All that is necessary is a detailed knowledge of the operation. Thus, operation standards can be set from a blueprint or a model of the product. It is not necessary or even advisable to wait until the product is in production before accurate man power requirements can be determined. This procedure not only yields time standards at the outset of production, but it eliminates the usual problem of what to do with surplus employees when methods are improved *after* the operation is under way.

Plant managers are coming to realize that manufacturing methods that they have been using over a period of years are costly and wasteful of human effort. In a great many cases these methods are being replaced with sound practices that do not involve capital investment. When we realize that the employees in industry are our biggest and most important asset, then we must logically conclude that training the employees in proper methods of work is one of the most important functions of engineers and of the industrial engineer in particular. No matter how good a new method may appear to be, it is worth less than nothing if it is not put into practice. The modern way of installing methods-improvement work is to "sell" the improvements to the employees by means of an in-plant training program. In this way, foremen and group leaders are made methods conscious and all of the employees are made a part of the methods-improvement program.

The practice of paying employees by the hour instead of compensating them in proportion to their productive output is fast disappearing from the scene. Modern management has discovered that it cannot compete cost-wise with the plant that uses an effective wage incentive plan for both its direct and indirect employees. Wage incentives have the double-barreled effect of making it possible for the employees to earn more money by producing more goods

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LONG-TERM LOAD TEST OF NAILED CONSTRUCTION

By M. W. JACKSON*

The common nail, though highly regarded and universally used for private home construction, is seldom employed in heavier structures subjected to greater loads. In the following article, the author reports work performed at Georgia Tech which indicates that nailed joints are both feasible and practicable for intermediate-size engineered structures. His work may lead to more rapid and less costly construction of such structures.

The utility of the common wire nail in joining the wooden members of engineered structures is often overlooked. While nails are, of course, indispensible for light frame construction, many engineers hesitate to specify them for larger structures which may be built of two-inch and three-inch lumber. If an engineer specifies nailed construction, he may run into two difficulties. First, some carpenters feel that no engineer can tell *them* how many nails to drive. Second, other carpenters have ruined good designs by driving so many nails, when the number is not specified, that the joint is completely splintered.

To investigate the use of nails for moderate size structures, two flat-top trusses were built with spans of 27 feet, designed to be placed seven feet center to center. The design as shown in Figure 2 corresponds to the trusses used in moderate size stores, garages or shop buildings.

*Assistant Professor of Civil Engineering, University of Colorado.

Figure 1. Part of the truss system set up at Georgia Tech to study nailed construction.

First it was necessary to determine the allowable load for a common wire nail in shear when driven across the grain. It seemed desirable to use 40d nails, five inches in length. For permanent construction with penetration of not less than two-thirds the length of the nail into the block receiving the point, the Forest Products Laboratory recommends a load of 175 pounds per nail of this size. Its recommendations permit the use of higher loads "if the character of the work is such that it appears safe . . . or if in the opinion of the designer it is felt that the factors of safety used are generally too conservative." A factor of safety of approximately six based on ultimate failure in laboratory tests is used. The value of 175 pounds may be increased if prebored holes slightly smaller than the nail diameter are used.

The Uniform Building Code (Sec. 2313c) allows a value of 270 pounds for a 40d nail driven across grain. It further specifies that nails shall not be driven closer together than one-half their length unless driven in bored holes nor closer to the edge of the timber than one-quarter their length. A penetration of one-half the length into the block receiving the point is required.

In the truss design the size of the members was controlled principally by the joint requirements. This explains the design of the second vertical from the end of the truss. The nail spacings, in general, followed the recommendations of the Uniform Building Code. The trusses were designed using No. 2 dimension southern pine, either 2x6's or 2x8's (surfaced four sides). The 40d nails penetrated three thicknesses at each connection, but the load on the nail was considered controlled by a single shear plane. If a value of 175 pounds per nail were allowable, the design load for the trusses was 40 pounds per square foot. If 270 pounds per nail were allowable, the design load was 60 pounds per square foot. This would be equivalent to a very heavy roof load or a light floor load. These design loads and the subsequent applied loads are based on the total load for a 14-foot width of roof which the trusses would be expected to carry.

In fabricating the trusses, the proper lengths of the members were laid out flat on the ground. A camber of one inch was placed in the top chord at the splice. The locations of nails were marked, and the first nail was driven to hold the members in position. Holes 3/16 of an inch in diameter for all of the other nails were made with a hand electric drill, and then

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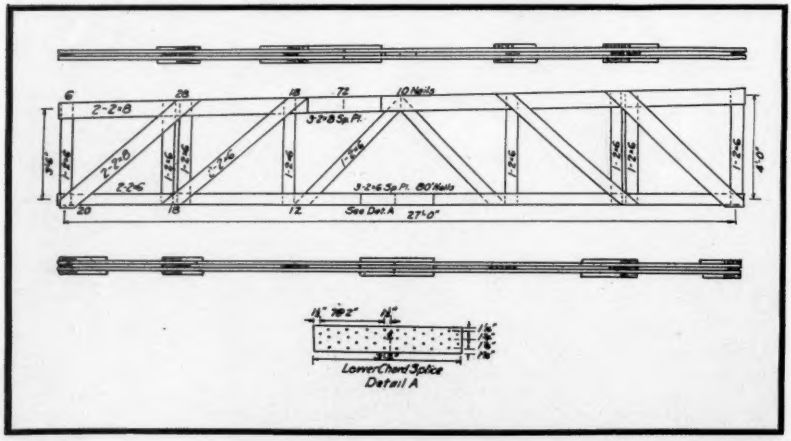

Figure 2. Design details of a test truss.

DIGESTS OF GRADUATE THESES
MECHANICAL ENGINEERING
1949 - 1950

Digests of theses submitted during 1949-1950 in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering are presented below. Theses submitted in the following fields will be carried at a later date: Electrical Engineering, Ceramic Engineering, Industrial Management, Mechanical Engineering, Physics, Safety Engineering and Textile Engineering.

Joseph Wendell Endsley, *Analysis of the Characteristics of a Panel Heating System in a Public Library*. Faculty advisor: Professor H. W. Mason.

Data taken concerning the heating characteristics of the East Atlanta Branch Library, a building heated by means of a panel heating system, were compared with data taken in two other public libraries of similar construction having conventional-type heating systems. The object of the analysis was to determine as nearly as possible the heating characteristics of the panel heating system as compared with the other two types of system insofar as comfort and economy are concerned. A general description of the buildings and heating systems is given, and the method of obtaining data is described.

The characteristics of the panel heating system are compared with those of the conventional systems regarding temperature control, temperature stratification, mean radiant temperature, relative humidity and heat input. Special peculiarities of the system are discussed and characteristic curves, photographs and data are presented to substantiate the statements made.

Albert Wellington Hainlin, *The Application of Solar Radiation to Comfort Cooling*. Faculty advisor: Professor M. J. Goglia.

An outline is presented whereby an absorption refrigeration machine may be constructed to operate on solar energy. A solar radiation analysis, which shows the direction from which the greatest amount of energy may be received during the summer, is given. Particular emphasis is placed on the design of a solar collector since it is the heat source which is distinctive. The suggested arrangement features a split collector, the reflectors of which are free to rotate in a vertical direction to follow the sun's changes in altitude. A simple mechanism actuated by the sun is described to keep the reflector in step with the sun. Basic data are given for the determination of net heat gain per square foot of collector surface, the number of glass cover plates and the size of reflector for a given outlet temperature. An original solution is offered for the determination of the direct radiation factor between an infinite tube and a semi-infinite plane.

From all appearances systems of the type studied might compete favorably with conventional cooling systems, but it is undetermined whether or not they could be installed cheaply enough for wide-spread use in homes.

Charley Scott, *Specific Heat Lag in Gases*. Faculty advisor: Professor M. J. Goglia.

The existence of a lag, or departure from equilibrium conditions, in a gas undergoing rapid changes in pressure or temperature, has been demonstrated experimentally and analytically by investigators interested in the phenomena concerning the absorption of sound and dispersion of sound velocity with frequency in gases. The basic theory of specific heat is presented and a brief review of the sound absorption investigations is given.

Kantrowitz has developed analytical expressions for determining a "total head defect" due to the specific heat lag during and after a compression of a gas at the nose of an impact tube. The work of Kantrowitz was carefully studied and is explained. An apparatus similar to that employed by Kantrowitz was designed to check the present data and for use in future investigations.

Arthur Conrad Stucki, *Air Friction—Its Role in Textile Spindle Power Consumption.* Faculty advisor: Professor R. L. Allen.

The relationships existing between total power input to a spindle and its components of dissipation, bearing friction and air friction, were measured and analyzed. These measurements were made at various spindle fullness, variable oil viscosities and with spindle speeds between 5,000 and 10,000 rpm. The Saybolt Universal Viscosities of oils used were 216, 189, 102.6, 83.5 and 70.8, all at 100° F.

The air frictional drag was found to range from 2.5 per cent of the bearing friction at 5,000 spindle rpm with an empty spindle and 216 SUV oil to 208 per cent of the bearing friction at 10,000 spindle rpm with a full spindle and 70.8 SUV oil. The air friction depends only upon fullness of the bobbin, spindle rpm and the yarn roughness factor. The procedure used isolates the air friction power for the particular yarn involved, allowing any power savings resulting from improvement of bearing design or lubrication to be related directly to the bearing. A study of total savings resulting from improved lubrication is included.

ROLES OF UNIVERSITIES

Continued from Page 4

fields of interest to the Department of Defense. This delimitation does not mean, however, that the Department may not find itself making use of a new discovery in some apparently irrelevant field.

Basic research will receive additional important support from the Federal Government as the program of the National Science Foundation gets under way. Under its enabling legislation, the Foundation is directed "to initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering and other sciences, by making contracts or other arrangements (including grants, loans and other forms of assistance) for the conduct of such basic scientific research and to appraise the impact of research upon industrial developments and upon the general welfare."

Let us hope that the universities with the support and assistance which government funds can give will be able to continue to provide refuge for what Dr. Conant calls the "uncommitted investigator" as distinguished from "programmatic research."

In explaining this differentiation, he says: "An individual laboratory which has undertaken to explore a particular segment of a scientific field for whatever reason is committed to a program." The "uncommitted investigator," is the rapidly disappearing species of amateur scientist and lone inventor who "were free as the wind in choosing from day to day the subject on which to focus their intellectual energies." It was from "uncommitted investigators" like Faraday that we have the accidental discoveries on which modern science is built.

The second great contribution which the universities can make is to produce the kind of trained scientists and engineers which constitute the real measurement of the strength of our program. Give us not "slide-rule men" merely, but men who have brains, energy, and imagination.

I have already suggested that a shortage of such men may constitute the limiting factor in our present plans for expanding the research and development program. We are handicapped somewhat in our assessment of the situation by lack of firm figures as to the total supply of technically trained persons and their present disposition. The Bureau of Labor Statistics estimates the total number of engineers and scientists in the United States to be 575,000 of which only about six per cent hold doctorate degrees. This figure is fairly meaningless, however, for it includes many persons with such training who are not following their professions. A more realistic estimate is that of the President's Scientific Research Board which predicted something like 190 thousand engineers and scientists in industry, Government, research, and teaching by 1951. According to this report, the distribution is roughly 41 per cent in universities and non-profit institutions, 41 per cent in industry, and 18 per cent in the Government.

Even on the basis of the rather tentative figures available, it is obvious that the demands for engineers and scientists are high. The military departments have indicated additional over-all requirements for fiscal

year 1952, of 5,700 military and 12,700 civilian scientists and engineers. Ten large industrial organizations sampled indicated a need of approximately 6,000 additional engineers for their expanding programs. In response to a small sampling by our staff, 13 engineering schools indicated that each of last year's engineer graduates received an average of three offers of technical positions.

The situation is aggravated by pirating of personnel between various activities and, as a result, there is a continued trend toward salary and wage spiralling, to say nothing of the time and money wasted on training and re-training personnel. It would be commendable if all companies and institutions with defense contracts observed the practice of Research and Development Laboratories in the Los Angeles area who recently advertised in the New York Times for precision machinists for guided missiles work but included the following stipulation in the advertisement "Please do not apply if you are already engaged to the fullest extent on urgent military projects."

Another complicating factor at the present is uncertainty as to how Selective Service requirements and deferments are going to be worked out. The recent Executive Order permitting deferments on the basis of class standing or scores in aptitude tests will probably make possible almost normal college attendance. There has been, as you know, considerable criticism of this plan, however, and the final resolution of the matter depends upon Congressional action on current Selective Service legislation.

Regardless of how the matter is decided, the fact remains that there will still be needed a large number of scientists and engineers for military research and development contracts, for teaching, for industrial production, for civil defense and other civilian needs, and certainly for the military Services.

From a long-range point of view the solution must lie in assuring a continuous flow of science and technical students through colleges and universities. It is hoped that Selective Service laws and regulations will be worked out in such a way as to make this possible. Now that the National Science Foundation is at last under way, the activation of its scholarship program will eventually make it possible for a greater number of students with scientific and technical aptitudes to acquire the training which they should have and which they cannot afford out of their own pockets.

For the immediate future there are a few sources from which additional engineers and scientists may be drawn for military research and development. A number of engineers and scientists who are now working on non-defense items for the civilian economy can be diverted to defense work. It is estimated that at present only about 35 per cent of the industrial research and development capacity is devoted to research and development for defense. However, a number of large industrial firms which have research and development capacity also have production contracts for the defense effort, and a certain number of their technical personnel must be retained for this phase of their activities.

A second source of additional manpower will be the June graduating classes, and although defense research and development will have to compete with other activities we shall probably get a substantial share.

A few research engineers may be diverted from production or sales engineering, but this source is not altogether a satisfactory one because of the amount of additional training that is necessary before sales engineers can participate effectively in research activities. Another source of "manpower" which has been overlooked in this field is womanpower. Although the number of women graduates in science and technical subjects is relatively small, a more consistent effort should be made to use those that are available. Women should also be utilized to a much greater extent in drafting and other auxiliary tasks in order to free senior scientists and engineers for the tasks for which they have been especially trained.

It appears, also, that we should exercise greater care in conserving the technical manpower that is available. If necessary, workweeks can be lengthened. Those who would normally retire can be permitted—in fact, they should be urged—to stay on where their competence warrants it. Finally, every employer of scientific manpower should determine definitely that each technically trained person is being employed to the

limit of his skills and is not spending part of his time on non-technical tasks which persons in greater supply could perform adequately.

To sum up the scientific manpower situation: the extent to which we solve it intelligently is apt to be the ultimate measure of success not only of the military program but of the national research and development effort as well.

In this matter, the Georgia Institute of Technology has made and will continue to make an important contribution. In fact, Georgia Tech may well assume a position of active leadership, as the research potential of the South begins to take shape. No one will dispute the fact that for obvious reasons, the South has not been one of the centers of research and development. In the first place, the economy of the Southern states was, in the beginning, largely agricultural. As such, it did not provide the stimulus for the growth of the kind of research and development activities which grew out of large industrial enterprises. When a new industrial activity began to emerge in the South, it was centered in the textile industry, which historically has returned a proportionately smaller share of its profits to research and development. Such things come about through circumstance rather than design, but the effects can be far-reaching. A case in point was made several years ago, by Lloyd V. Berkner, recently named President of Associated Universities. Addressing the National Electronics Conference in Chicago, he said: "During the past war a group of electronics manufacturers from the Chicago area asked for a conference with the Secretary of the Navy. They pointed out that they had enormous factory capacity, a good source of labor, and plenty of machinery. They were anxious to throw more of their facilities into the war effort. But the bulk of new electronics business was going to firms in the East! Why?

"As you all know, there was tremendous evolution in application and form of electronic equipment during the war. This was not a matter of whim—it was the result of the need to meet and forestall the evolution of enemy tactics. The source of this new equipment was the laboratory where the scientist and engineer joined with the tactician and strategist to devise the most effective means of combating each new or anticipated tactic. It was a matter of necessity, then, that the Army and the Navy turn to organizations whose research and development laboratories had the capacity, quality, and vigor to provide the solutions needed, and usually the production contracts followed. Unfortunately for the equitable geographic distribution of such contracts, the majority of adequate industrial electronic laboratory facilities were at that time in the East.

"Here, then, is a specific example where the life of a community was adversely affected by a shortage in research and development. Here is an example of saturation in our regenerative system of progressive industry. Continued growth and welfare depend importantly on renewal and expansion of industry through constant generation and advance of ideas. It behooves the engineer, the business man, and the financier to protect his industry and his community, in proportion to his business and investment, with the safeguards of creative thinking evolved by research and invention. Support of research is an economic matter required for the welfare of the industry. But it is also a cultural matter deserving the support of the whole community. Its planning requires initiative and effort from the financier, the educator, the professional man, and the merchant alike. We need here the same kind of foresight demonstrated by the pioneers who taxed themselves under the most adverse conditions to establish our universities."

In the South I believe that a new day is dawning for research and development activities. There is already a small volume of research and development contracts in the area, and undoubtedly the amount will grow as facilities and personnel become available. In your neighboring state, Tennessee, the Arnold Engineering Development Center is under way at Tullahoma and will undoubtedly become one of the large research centers of the United States. It will be looking to Georgia Tech for the bright young engineers needed to staff such an enterprise. If the military research and development program is to be carried out at

the level contemplated for the next few years, full use must be made of potential facilities not now engaged on defense work.

At this point, however, the seller must seek the buyer. The Department of Defense has not yet developed complete information regarding all research and development facilities in the country, their capabilities and potentialities. Therefore, the college, university or other would-be contractor which believes it has something to offer for defense research and development will do well to make that fact known in Washington, rather than to wait for the military departments to make the discovery for themselves. In the RDB we have one office assigned to the task of guiding contractors to the many places in the three military Departments which contract for research and development. Even though no immediate need may be apparent at the time of inquiry, it is well to have qualifications and facilities a matter of record with these offices. Furthermore, since universities and colleges are new at this sort of thing, they will find that it will pay them to employ an able and energetic business representative who knows his way thoroughly among the perils and pitfalls of large-scale contractual arrangements. The task is definitely not one for the boys in the ivory tower.

Here at Georgia Tech, you are already making a substantial contribution to the defense program. I understand that you have a rather substantial volume of research and development contracts with the Army, the Navy, and the Air Force. One project with which I happen to be familiar, personally, concerns the protection of merchant shipping, a problem which carries a very high priority. The presence on your campus of one of the six Daniel Guggenheim Schools of Aeronautics means that you are training the aeronautical engineers for which there is such heavy demand by both the defense program and the civilian industry. And in addition, you are carrying an active ROTC program for all three Services. You may well take pride in these important defense activities.

I hope, however, that if you are not utilizing your defense potential to the fullest, you will not be content to rest upon your substantial laurels. As I tried to suggest in these remarks, the effects of an active research and development program are cumulative. The presence of a good staff and excellent facilities tends to invite research and development contracts; the growth of contractual activity tends to produce new facilities and to attract sound investigators.

These are uncertain and somewhat difficult times for colleges and universities: for students, professors, and administrative staffs alike. But even those who look with disfavor and suspicion upon all forms of government support of academic institutions will do well to re-examine the situation to see if perhaps the expanding program of government activity may not provide the bridge between the confused present and some safer, happier, if far-off future when the campus may once more dedicate itself safely to the pursuit of the peaceful arts.

FLUIDIZED POWDER

Continued from Page 6

one might use the powdered coke produced by an oven of the fluidized powder type as the charge to a fluidized powder gas producer, a style of unit which has already undergone considerable study.[2] The producer gas, in turn, could be used as the fuel for open hearth furnaces or as the gas employed to convert fluidized iron ore to iron which could then be blown into open hearths for conversion to steel. The gas required for fluidizing the coal during distillation might be obtained by recycling some of the coke-oven gas itself or by using a portion of the producer gas. In similar fashion, one might fluidize powdered hardwood with part of the gases evolved from the wood itself or with producer gas manufactured from part of the charcoal product. The net output of charcoal might find a use as fuel or be enhanced in value by activating it with steam to form an adsorbent which could then be used to recover solvents from gases by contact in a conventional fluidized powder unit or some modification designed to favor countercurrent action. Distillation of pine stumps could perhaps be accomplished most conveniently in a two-stage setup: the first, a steam distillation to recover turpentine and pine oil; the second, a distillation under vacuum to remove the

rosin. Some experience exists in other fields to suggest that fluidization under vacuum is probably quite feasible. In any of the distillation steps outlined above, heat could be supplied or removed by one or another of several convenient means, such as partial combustion of recycled gas, a heat exchanger within the appartus itself, an external exchanger through which the charge is circulated by the gas lift principle, or injection of water into the hot fluidizing gases.

Difficulties in Fluid Process

Like many new processes, the fluidized powder technique has its drawbacks as well as advantages. Among these should certainly be mentioned the cost of reducing the charge to powdered form, the expense entailed in compressing the relatively large quantity of fluidizing gas to a degree sufficient to support the fluidized bed, the danger that the particles undergoing distillation may stick together and clog the reaction vessel as a result of the formation of tars, and the need for equipment to recover valuable chemicals from the relatively large quantity of noncondensible fluidizing gas.

While it is not out of the question to charge a succession of batches as is done in the case of by-product coke ovens and retorts for the distillation of wood, it would probably be most practical, from the point of view of ease of operation and control, to feed the charge to a fluidized powder distilling unit continuously and at the same time withdraw coke or charcoal, as the case may be, at a steady rate. Such a procedure introduces a problem in that the mixing of materials within a fluidized bed is so complete that the composition of the bed is substantially the same at all points. Thus, if one is to withdraw a solid product which is largely dry coke or charcoal, the entire body of the fluidized bed must have a high proportion of particles of dry coke or charcoal and a relatively small proportion of particles of charge in the early stages of distillation. The result is that one must provide space not only for the particles of charge which are actually being distilled but also for a large number of additional particles which have already been distilled. The effect can be reduced but not eliminated by the use of a two-stage apparatus with the first unit distilling the bulk of the gas from the charge and the second acting as a clean-up unit to strip the coke or charcoal dry.

Current Investigations

In order to assess the economics of distilling a particular kind of wood or coal by the fluidized powder technique, one must be able to put down numbers—quantities, pressures, power requirements, yields, etc.—for all the many factors, both pro and con, which have been mentioned in preceding paragraphs. At the present time, experimental programs with the object of obtaining pertinent basic information are under way in at least two institutions, Georgia Tech and Stanford University.

The work at Georgia Tech has thus far been confined to small-scale experiments on the distillation of hardwood. One reason for this choice of raw material is the existence of a hardwood distillation industry in the South. In addition, when compared with other likely materials, hardwood seems to offer the fewest problems in laboratory manipulations and is hence a logical choice for initial experiments. While hardwood is the only material that has been tried to date at Georgia Tech, the appartus constructed for the purpose should be adaptable for experiments with other types of charge, and further work is being planned.

Preliminary results on hardwood, reported in 1948,[3] are noteworthy in two respects: the discovery of an effective method for preventing the distilling particles from sticking to each other; and the achievement of substantially complete distillation in remarkably short times—of the order of two hours at 400° C. The preliminary data on yields are much less definite, since they depend on an estimate of the amount of solvents contained in the noncondensible gases; but it seems clear that the yields of wood alcohol and acetic acid at least equal and perhaps exceed those now obtained commercially.

More recent work on hardwood, to be published in the near future, shows that the time of distillation can be reduced to as little as thirty minutes at 400° C. by means of a change in the setup, which has the effect of improving the degree of fluidization. A complete material balance on the

process, including a measurement of the non-condensible gases and recovery of the solvent vapors therein, discloses that the amount of solvent in the gases is less than originally estimated and that the total yield of wood alcohol and acetic acid obtained at 400° C. is about the same as the yields reported for present commercial operations. Attempts are being made to run the apparatus for a sufficient time to accumulate a sample of tar large enough for an accurate and complete analysis. Such an analysis may indicate that the short reaction time characteristic of the fluidized powder unit has the effect of minimizing thermal decomposition of valuable constituents (many of which are probably unstable at distillation temperatures) and producing a richer tar than that from conventional retorts. However, in the absence of data on this point, the probable advantages of a fluidized powder unit for the distillation of hardwood appear to be economy of labor due to continuous operation and a reduction in the size of appartus required for a given capacity.

At Stanford attention has centered on the distillation of redwood waste, disposal of which is a major problem of the lumber industry on the West Coast. Small-scale experiments have indicated that the yields of wood alcohol and acetic acid from redwood are low. However, the yields of other chemicals are so attractive that a unit has been constructed for further study on a pilot plant scale.[4]

* * * *

What, then, is the present status of the distillation of wood and coal by the fluidized powder technique? Because of the small scale of the experiments and the small number of raw materials that have been tried, it is too soon to gauge the ultimate worth of the process to industry. However, the work thus far is encouraging It offers hope for important economies in labor and materials. There are a number of indications that it may lead to the production of richer oils and tars. Finally, in the broad view, it may help us to be more efficient in our use of two major natural resources.

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INDUSTRIAL ENGINEERING

Continued from Page 10

and at the same time lowering the cost of manufacturing the goods.

In order to be successful, any industrial engineering work must convince the employees and the management that they will get more job security, more money in the form of wages or profits and therefore a higher standard of living. This realization can be accomplished by making the employees a part of any industrial engineering program. If the employees understand the aims and principles of management and if good industrial relations have been established, then cooperation for mutual benefit of labor and management is the logical end result. Every good professional industrial engineer understands that Human Engineering is the most important phase of his work.

CORRELATION FUNCTION

Continued from Page 8

are n zero crossings in any duration τ is given by

$$P(n,\tau)=\frac{(K\tau)^n}{n!}\ e^{-K\tau}\ .$$

The autocorrelation function in this problem is

$$\phi(\tau)=a^2e^{-2K|\tau|}$$

and is shown in Figure 5.

A random process may possess a hidden periodic component. Consider the wave consisting of duration-modulated pulses with equally spaced leading edges as shown in Figure 6. Let the leading edges of the pulses be spaced at intervals of length $2p$. Let the pulse duration, s, vary independently between the limits of zero and p with a uniform distribution. The autocorrelation

function consists of a periodic component (I) and a random component (II).

(I) $$\phi_1(\tau)=\frac{a^2}{4p^2}(p-|\tau|)^2$$

$$-\frac{a^2}{12p^3}(p-|\tau|)^3 \qquad (|\tau|<p)$$

$$\phi_1(\tau)=\frac{a^2}{4p^2}(p-|\tau|)^2$$

$$+\frac{a^2}{12p^3}(p-|\tau|)^3 \qquad (p<|\tau|<2p)$$

(II) $$\phi_2(\tau)=\frac{a^2}{12p^3}(p-|\tau|)^3 \qquad (|\tau|<p)$$

$$\phi_2(\tau)=0 \qquad (|\tau|>p).$$

The autocorrelation function is shown in Figure 7.

The preceding examples illustrate the following properties of the autocorrelation function of a random process. The value at $\tau=0$ is the greatest value of $\phi(\tau)$. The autocorrelation function is an even function. When no hidden periodic component is present, the limiting value of $\phi(\tau)$ as $\tau \to \infty$ is the square of the mean of the function.

The autocorrelation function is useful in obtaining the power spectrum of a random process. To understand this, consider first the case of a periodic function. Let

$$V=A\cos(\omega t+\theta),$$

where A is the amplitude, ω is the frequency, and θ is the phase. Then

$$\phi(\tau)=\frac{\omega}{2\pi}\int_0^{\frac{2\pi}{\omega}} V(t)\,V(t+\tau)\,dt,$$

$$=1/2\,A^2\cos\omega\tau.$$

The autocorrelation function is of the same form as the original function. The amplitude of the autocorrelation function is one half the square of the amplitude of the original function; frequency has been preserved; and the phase angle has been lost.

Now if $V(t)$ is a general periodic function, it can be represented by a Fourier series; i.e.,

$$V(t)=\sum_{n=-\infty}^{\infty} f(n)\,e^{jn\omega t},$$

where ω is the fundamental angular frequency, and $f(n)$ is the complex line spectrum which is given by

$$f(n)=\frac{1}{T}\int_0^T V(t)e^{-jn\omega t}dt,$$

where T is a complete period. The autocorrelation function of $V(t)$ is

$$\phi(\tau)=\frac{1}{T}\int_0^T V(t)V(t+\tau)dt$$

$$=\sum_{n=-\infty}^{\infty}|f(n)|^2e^{jn\omega\tau}$$

If the power spectrum of $V(t)$ is denoted by $\Phi(n)$; i.e.,

$$\Phi(n)=|f(n)|^2,$$

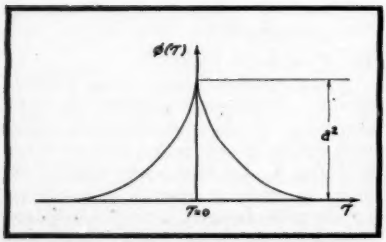

Figure 5.

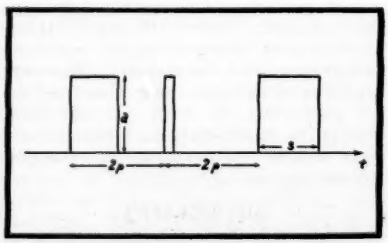

Figure 6.

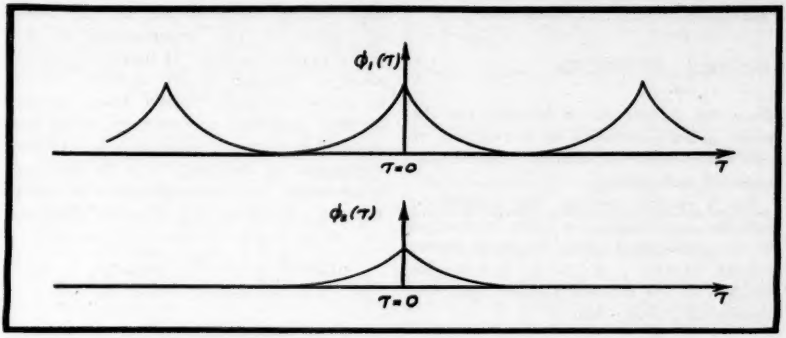

Figure 7.

then*

(3)
$$\phi(\tau)=\sum_{n=-\infty}^{\infty}\varphi(n)e^{jn\omega\tau},$$

and

(4)
$$\varphi(n)=\frac{1}{T}\int_0^T\phi(\tau)e^{-jn\omega\tau}d\tau.$$

From Equations (3) and (4), it is seen that the harmonic analysis of the autocorrelation function of a periodic function, $V(t)$, yields the power spectrum of $V(t)$, and a synthesis of the harmonics regains the autocorrelation function.

Next, consider a non-periodic function $V(t)$ $(-\infty<t<\infty)$. It is assumed that

$$\int_{-\infty}^{\infty}V^2(t)dt$$

is finite. Let

$$f(\omega)=\int_{-\infty}^{\infty}V(t)e^{-j\omega t}dt$$

be the Fourier Transform of $V(t)$. Then

(5)
$$2\pi\int_{-\infty}^{\infty}|f(\omega)|^2e^{j\omega\tau}d\omega=\int_{-\infty}^{\infty}V(t)V(t+\tau)dt.$$

The autocorrelation function for non-periodic functions is defined to be

$$\phi(\tau)=\int_{-\infty}^{\infty}V(t)V(t+\tau)dt.$$

It should be noted that the autocorrelation function does not involve averaging over an interval, because of the assumption that the integral of the square of $V(t)$ is finite. Let

$$\Phi(\omega)=2\pi|f(\omega)|^2.$$

If τ is set equal to zero in Equation (5), then

(6)
$$\int_{-\infty}^{\infty}\varphi(\omega)d\omega=\int_{-\infty}^{\infty}V^2(t)dt.$$

In Equation (6), the right-hand member is the total energy, and hence $\Phi(\omega)$ is the energy density spectrum of $V(t)$. Equation (5) can be written

$$\phi(\tau)=\int_{-\infty}^{\infty}\varphi(\omega)e^{j\omega\tau}d\omega,$$

and hence,

$$\varphi(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}\phi(\tau)e^{-j\omega\tau}d\tau.$$

Since $\phi(T)$ and $\Phi(\omega)$ are even functions, then

$$\phi(\tau)=\int_{-\infty}^{\infty}\varphi(\omega)\cos\omega\tau d\omega,$$

* *Because of limitations in type, the symbols* Φ *and* φ *are used interchangeably, with the same meaning, throughout this article.*

and

$$\varphi(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}\phi(\tau)\cos\omega\tau d\tau .$$

Hence, the autocorrelation function and the energy density spectrum of a function of finite total energy are Fourier cosine transforms of each other.

For a random process, the assumption that the total energy is finite is replaced by the assumption that the mean power is finite. If $x(t)$ $(-\infty<t<\infty)$ is a member function of the random process, then this assumption means that

$$\lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}x^2(t)dt$$

is finite. If $\Phi(\omega)$ is the power density spectrum, then

$$\phi(\tau)=\lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}v(t)v(t+\tau)dt$$

$$=\int_{-\infty}^{\infty}\varphi(\omega)e^{j\omega\tau}d\omega$$

and

$$\varphi(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}\phi(\tau)e^{-j\omega\tau}d\tau .$$

Since $\phi(\tau)$ and $\Phi(\omega)$ are even functions, it follows that

$$(7)\quad \phi(\tau)=\int_{-\infty}^{\infty}\varphi(\omega)\cos\omega\tau d\omega,$$

and

$$(8)\quad \varphi(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}\phi(\tau)\cos\omega\tau d\tau .$$

Equations (7) and (8) express the fact that the autocorrelation function and the power density spectrum are Fourier cosine transforms of each other. The results in Equations (7) an (8) are known as Wiener's theorem.

Wiener's theorem provides a simple means for the analysis of random phenomena. To illustrate the application of this theorem, consider the flat top wave of Figure 4. The determination of the power density spectrum by means of Fourier series or Fourier integral theories cannot be carried through, because these theories are not applicable to functions which are specified in terms of probability. An analytic expression for the function to be analyzed is necessary for the employment of these theories. However, by Wiener's theorem,

$$\varphi(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}a^2e^{-2k|\tau|}\cos\omega\tau d\tau ,$$

$$\varphi(\omega)=\frac{2Ka^2}{\pi(4k^2+\omega^2)}$$

A practical application of the autocorrelation function is illustrated in the determination of the power density spectrum which can, of course, be obtained directly by means of filters. However, at low frequencies direct determination by filtering requires the use of a "zero" bandwidth filter—thus imposing an equipment requirement which cannot be met at present. The autocorrelation method is actually a sort of filtering in the time domain as contrasted with direct filtering in the frequency domain. A zero bandwidth filter in the frequency domain corresponds to an extremely stable oscillator in the time domain. Since stable oscillators are much easier to build than zero bandwidth networks, the autocorrelation function offers a superior method for determination of the power density spectrum at low frequencies. The autocorrelation function can be readily obtained by means of an electronic correlator, and the power spectrum can be calculated as the Fourier cosine transform, utilizing a differential analyzer.

The autocorrelation technique has been applied successfully to the study of Brownian motion, colloidal statistics, thermodynamics and the theory of cosmic rays and showers. Under study at present are applications to the detection of radar signals in the presence of noise, design of gunnery fire control systems, analysis of business trends, weather forecasting and ocean wave analysis.

EDITOR'S NOTE: A correlator of advanced

design is now under construction at Georgia Tech. Details of its design, operation and application to the solution of research problems will be presented in a later issue.

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LOAD TEST

Continued from Page 12

all nails at one joint were driven. Very little construction time was used in drilling the holes.

The pair of trusses was erected on concrete pedestals and braced together as an actual roof structure would be. A two-inch plank roof was nailed to the top chord, and a waterproof roofing was applied. The plank roofers were 12-foot lengths, providing an overhang on the outside of the trusses and on the ends to protect them from the weather. Sideboards were placed on the roof to retain the load uniformly.

The trusses were allowed to remain in place a few days before subsequent load was applied. A uniformly distributed load of 1½-inch to ½-inch crushed stone was applied in three increments. This size stone provided a very low rate of absorption of moisture. The stone was exposed to rain, but the total load on the truss probably did not vary over three per cent due to the rain which drained through the stone and off of the roof very rapidly.

Deflection Measurements

Deflection measurements were made along the lower chords of the trusses on the outside of the trusses. The deflections were corrected for the effect of crushing at the supports. Deflections were measured from a steel wire stretched between fixed points by a constant weight to scratch marks on the nail heads. A mirror placed flat against the side of the truss was used to reflect the image of the wire for aligning the eye in reading a steel scale graduated to 1/100ths of an inch.

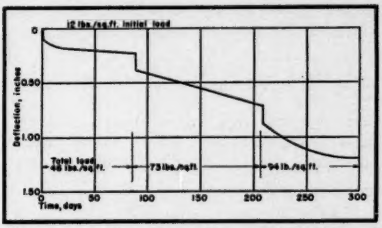

Figure 3. Average midspan deflection of the trusses plotted against time.

The average midspan deflections of the trusses are plotted against time in Figure 3. It was not practicable to take the deflection readings at regular time intervals. The zero deflection was established with the initial load of 12 pounds per square foot on the truss. A load of 34 pounds per square foot was applied for a total load of 46 pounds per square foot. On the basis of the elastic deflection of the truss, assuming no slip at the joints, the deflection should have been 0.10 inch for the increment of load added. The actual measurements revealed an initial deflection of 0.11 inch which continued to increase until it had reached 0.23 inch at the end of 88 days. This continuing deflection of the truss was not unexpected, since this is inherent in all timber construction.

For the second increment of load, the calculated value of the deflection was 0.08 inch; the actual immediate deflection was 0.15 inch, probably indicating a slip of the joints and bending of the nails as well as elastic deformation of the members. The final value at the end of 120 days was 0.38 inch.

For the third increment, the calculated value of deflection was 0.06 inch; the actual immediate deflection was 0.16 inch. The deflection at the end of 82 days was 0.31 inch.

For the final 82 days of the test, the

trusses were carrying a load of 94 pounds per square foot as compared with the design load of 40 or 60 pounds per square foot, depending on the recommendations followed. During the entire period of 290 days, the trusses were carrying at least 90 per cent of the design load of 40 pounds per square foot. The results were reassuring, since buildings are rarely called upon to carry the full design load for any great length of time. It is quite probable that some poor or inadequate construction has been saved by the fact that specified design loads rarely occur.

At the conclusion of the tests, the trusses were practically undamaged. The splice plates showed small longitudinal splits along the center, and the end diagonals were bowed noticeably. There was no appreciable splitting or deterioration of the joints. The nails remained tight. If the test trusses were redesigned, the end diagonals probably should have spacer blocks at mid length. Perhaps the splice plates also should be redesigned to minimize lateral restraint against movement due to moisture change in order to eliminate the small splits which develop.

On the basis of the trusses tested, it seems feasible and practicable to use nailed construction on intermediate-size engineered structures where good construction practices are followed. The design recommendations of the Forest Products Laboratory for allowable loads on nails are believed definitely conservative, and those of the Uniform Building Code seem satisfactory and reasonable.

INDIVIDUAL FACULTY RESEARCH

Continued from Page 2

school from the ranks of the *many good* to the level of the *few excellent*. Nothing has been said concerning the contribution of faculty research to useful knowledge and to the intellectual development of faculty researchers.

Almost everyone who reads today's newspapers can name a number of noted faculty research men, their respective institutions and their major contributions. If recognition were the only factor considered in evaluating faculty research, the conclusion would still have to be that it is highly desirable. Such men bring merited credit to themselves and to their schools.

Recognition, alone, is the least of the benefits of faculty research. True, those men known by their research accomplishments are most valued by their own schools and most sought after by rival institutions. This is primarily because they also are, by and large, the most inspiring teachers for the engineers of the future. Such men grow with their work, increasing the store of knowledge which they can impart to their students. Constantly coping with new problems, they develop fresh approaches which stimulate student thinking as well as their own. They do not dwell in ivory towers.

The contributions of teacher-researchers to scientific progress constitute the second major argument for faculty research. Thoroughly grounded in fundamentals by the nature of their teaching task, those of creative and inquiring minds are admirably fitted to attack unsolved problems. Using the facilities of their institutions and supported by relatively small appropriations from within or from without, they can and have made discoveries vital to the health, industrial progress and general advancement of our nation.

Georgia Tech, in common with other leading engineering schools, provides an atmosphere conducive to individual faculty research as well as participation by the faculty in the more extensive type of project research. The facilities of its library, its various schools and the Engineering Experiment Station are available to faculty members who wish to study problems. Perhaps even more important, Georgia Tech endeavors to surround keen faculty research men with others of like abilities in similar and related fields. Thus, each may benefit from the stimulus of the other to attain a high degree of productivity.